
Try to come up with an optimized cabinet design. Assume that it is made of 3/4" MDF.

Set up the invariants.

$\mathrm{Wall} \equiv .75 \cdot \mathrm{in}$

$\mathrm{BaffleWidth} \equiv 9 \cdot \mathrm{in}$

$\mathrm{RearPlateWidth} \equiv 15 \cdot \mathrm{in}$ $\qquad$ $\mathrm{RearPlateSetback} \equiv \mathrm{Wall}$

$V_{\mathrm{woofer}} \equiv 3.35 \cdot \mathrm{ft}^3$

$V_{\mathrm{midrange}} \equiv .85 \cdot \mathrm{ft}^3$ $\qquad$ Could go to 1.0 for a slightly lower Q

$\mathrm{FudgeFactor} \equiv .1$

$V_{\mathrm{optimal}} \equiv \left(V_{\mathrm{midrange}} + V_{\mathrm{woofer}}\right) \cdot (\mathrm{FudgeFactor} + 1)$

$\mathrm{CabinetHeight} \equiv 40 \cdot \mathrm{in}$

$\mathrm{DistanceToListener} \equiv 8 \cdot \mathrm{ft}$

$\mathrm{ListenerEarHeight} \equiv 3 \cdot \mathrm{ft} + 6 \cdot \mathrm{in}$

$\mathrm{WooferDiameter} \equiv 7 \cdot \mathrm{in}$

$\mathrm{TweeterDiameter} \equiv 13 \cdot \mathrm{cm}$

$\mathrm{DriverSpacing} \equiv 1 \cdot \mathrm{in}$

Figure out where the center of the tweeter sits.

$$\mathrm{DistanceFromTop} := \mathrm{WooferDiameter} + \frac{\mathrm{TweeterDiameter}}{2} + 2 \cdot \mathrm{DriverSpacing}$$

$$\mathrm{TweeterHeightFromFloor} := \mathrm{CabinetHeight} - \mathrm{TweeterDiameter}$$

Calculate the amount by which the baffle must be tilted back, in order to aim the tweeter (and the MTM radiation pattern) directly at the listener's nominal position.

$$OutsideSetbackAngle := \operatorname{atan}\left(\frac{ListenerEarHeight - TweeterHeightFromFloor}{DistanceToListener}\right)$$

$$OutsideSetbackDistance := CabinetHeight \cdot \tan(OutsideSetbackAngle)$$

$$BaffleHeight := \frac{CabinetHeight}{\cos(OutsideSetbackAngle)}$$

Show the calculated results so far

$$DistanceFromTop = 11.559 \cdot in$$

$$TweeterHeightFromFloor = 34.882 \cdot in$$

$$OutsideSetbackAngle = 4.241 \cdot deg$$

$$OutsideSetbackDistance = 2.966 \cdot in \qquad BaffleHeight = 40.11 \cdot in$$

Assume that the bottom of the longer (outside) wall is 24" long, as this is the maximum length of MDF that is conveniently available.

$$OutsideBottom := 24 \cdot in$$

Calculate the length of the longest diagonal, and use this to calculate the bottom of the inner wall.

$$BottomDiagonal := \sqrt{OutsideBottom^2 + BaffleWidth^2}$$

$$InsideBottom := \sqrt{BottomDiagonal^2 - RearPlateWidth^2}$$

Whatta we got?

$$BottomDiagonal = 25.632 \cdot in \qquad BottomDiagonal = 651.053 \cdot mm$$

$$InsideBottom = 20.785 \cdot in \qquad InsideBottom = 527.929 \cdot mm$$

Determine the interior angles. The inside-to-rear-corner angle is 90 degrees, as is the outside-to-front angle, hence we have two abutting right triangles. The outside-to-rear angle "Alpha" can be calculated as the sum of two subangles, based on the two right triangles. The inside-to-front angle "Beta" is 180 degrees minus Alpha.

$$\alpha_1 := \operatorname{atan}\left(\frac{BaffleWidth}{OutsideBottom}\right) \qquad \beta_1 := 90 \cdot deg - \alpha_1$$

$$\alpha_2 := \operatorname{atan}\left(\frac{InsideBottom}{RearPlateWidth}\right) \qquad \beta_2 := 90 \cdot deg - \alpha_2$$

$$\alpha := \alpha_1 + \alpha_2 \qquad \beta := \beta_1 + \beta_2$$

So, what are the angles?

$$\alpha = 74.739 \cdot deg \qquad \beta = 105.261 \cdot deg$$

The front and inside meet at an angle which is 90 degrees less than Beta

$$\text{InsideBladeAngle} := \beta - 90 \cdot \text{deg}$$

Figure out how far the outside end of the bottom hangs out past the inside, and how far from the inside wall this overhang is located.

$$\text{BottomPointOverhang} := \text{BaffleWidth} \cdot \sin(\text{InsideBladeAngle})$$

$$\text{BottomPointOffset} := \text{BaffleWidth} \cdot \cos(\text{InsideBladeAngle})$$

$$\text{BottomTotalLength} := \text{InsideBottom} + \text{BottomPointOverhang}$$

Let's see!

$\text{BottomPointOverhang} = 2.369 \cdot \text{in}$	$\text{BottomPointOverhang} = 60.173 \cdot \text{mm}$
$\text{BottomPointOffset} = 8.683 \cdot \text{in}$	$\text{BottomPointOffset} = 220.538 \cdot \text{mm}$
$\text{BottomTotalLength} = 23.154 \cdot \text{in}$	$\text{BottomTotalLength} = 588.102 \cdot \text{mm}$

The setback at the top of the inside wall is greater that the setback at the top of the outside, because the front baffle meets the inside at an obtuse angle.

$$\text{InsideSetbackAngle} := \frac{\text{OutsideSetbackAngle}}{\sin(\beta)}$$

$$\text{InsideSetbackDistance} := \text{CabinetHeight} \cdot \tan(\text{InsideSetbackAngle})$$

Show the inside setbacks

$$\text{InsideBladeAngle} = 15.261 \cdot \text{deg}$$

$$\text{InsideSetbackAngle} = 4.396 \cdot \text{deg}$$

$$\text{InsideSetbackDistance} = 3.075 \cdot \text{in}$$

$$\frac{\text{OutsideSetbackDistance}}{\cos(\text{InsideBladeAngle})} = 3.074 \cdot \text{in}$$ ...as a check

Calculate the top plate dimensions

$$\text{OutsideTop} := \text{OutsideBottom} - \text{OutsideSetbackDistance}$$

$$\text{InsideTop} := \text{InsideBottom} - \text{InsideSetbackDistance}$$

Calculate the long diagonal on the top, and from this calculate the width of the top of the baffle.

$$\text{TopDiagonal} := \sqrt{\text{InsideTop}^2 + \text{RearPlateWidth}^2}$$

$$\text{TopBaffleWidth} := \sqrt{\text{TopDiagonal}^2 - \text{OutsideTop}^2}$$

Display the dimensions of the top of the box

$OutsideTop = 21.034 \cdot in$ $OutsideTop = 534.267 \cdot mm$

$InsideTop = 17.71 \cdot in$ $InsideTop = 449.831 \cdot mm$

$TopBaffleWidth = 9.808 \cdot in$ $TopBaffleWidth = 249.135 \cdot mm$

$TopDiagonal = 23.209 \cdot in$ $TopDiagonal = 589.499 \cdot mm$

Determine the interior angles at the top of the box.

$$A_1 := \mathrm{atan}\left(\frac{TopBaffleWidth}{OutsideTop}\right) \qquad B_1 := 90 \cdot deg - A_1$$

$$A_2 := \mathrm{atan}\left(\frac{InsideTop}{RearPlateWidth}\right) \qquad B_2 := 90 \cdot deg - A_2$$

$$A := A_1 + A_2 \qquad B := B_1 + B_2$$

So, what are the angles?

$A = 74.736 \cdot deg$ $B = 105.264 \cdot deg$

The front and inside meet at an angle which is 90 degrees less than Beta

$$InsideBladeAngle_{top} := B - 90 \cdot deg$$

Figure out how far the outside end of the top hangs out past the inside, and how far from the inside wall this overhang is located.

$$TopPointOverhang := TopBaffleWidth \cdot \sin(InsideBladeAngle_{top})$$

$$TopPointOffset := TopBaffleWidth \cdot \cos(InsideBladeAngle_{top})$$

$$TopTotalLength := InsideTop + TopPointOverhang$$

Let's see!

$TopPointOverhang = 2.582 \cdot in$ $TopPointOverhang = 65.588 \cdot mm$

$TopPointOffset = 9.462 \cdot in$ $TopPointOffset = 240.347 \cdot mm$

$TopTotalLength = 20.292 \cdot in$ $TopTotalLength = 515.42 \cdot mm$

Now, let's calculate the actual box volume achieved. Calculate the areas of the top and bottom, adjusting for the thickness of the MDF walls. Take the average of the two. Multiply by the height of the cabinet, again compensating for the thickness of the MDF.

$$BottomTriangle_1 := \frac{((OutsideBottom - RearPlateSetback) - Wall \cdot 2) \cdot (BaffleWidth - Wall \cdot 2)}{2}$$

$$BottomTriangle_2 := \frac{((InsideBottom - RearPlateSetback) - Wall \cdot 2) \cdot (RearPlateWidth - Wall \cdot 2)}{2}$$

$$BottomArea := BottomTriangle_1 + BottomTriangle_2$$

$$TopTriangle_1 := \frac{((OutsideTop - RearPlateSetback) - Wall \cdot 2) \cdot (TopBaffleWidth - Wall \cdot 2)}{2}$$

$$TopTriangle_2 := \frac{((InsideTop - RearPlateSetback) - Wall \cdot 2) \cdot (RearPlateWidth - Wall \cdot 2)}{2}$$

$$TopArea := TopTriangle_1 + TopTriangle_2$$

$$MidlineArea := \frac{BottomArea + TopArea}{2}$$

$$MidlineArea = 194.53 \cdot in^2$$

$$ActualVolume := MidlineArea \cdot (CabinetHeight - 2 \cdot Wall)$$

$$ActualVolume = 4.334 \cdot ft^3$$

$$V_{optimal} = 4.62 \cdot ft^3$$

$$V_{woofer} := ActualVolume - V_{midrange} \cdot (1 + FudgeFactor)$$

$$V_{woofer} = 3.399 \cdot ft^3$$

Close enough for folk music, I think. The 1259 is said to give good results in sealed boxes from 2.5 feet on up, with 3.5 feet being about optimal. Even if the midrange compartment ends up a trifle on the large side, and if braces and drivers and etc. take up more than 10% of the cabinet room, the woofer should still have over 3 cubic feet to work into. Stuff in some Dacron and the resulting cabinet Q should be plenty low enough for good sound.

OK, now let's figure out where the subenclosure back wall should be replaced.

The subenclosure wall will be parallel to the rear wall of the box, and will thus be at an angle (InsideBladeAngle) with respect to the front baffle. The subwall will be vertical, and at the inside top it will be set back from the baffle by a specific distance (let's call it D). At all other points, the subwall will be further away from the front baffle.

Create a set of formulae which will give the total area between subwall and baffle for any specified distance D.

$$InsideTopBaffle := TopBaffleWidth - 2 \cdot Wall \qquad InsideTopBaffle = 8.308 \cdot in$$

$$R := InsideTopBaffle \cdot \sin(InsideBladeAngle) \qquad R = 2.187 \cdot in$$

$$F := R \cdot \cos(InsideBladeAngle) \qquad F = 2.11 \cdot in$$

$$Q := \sqrt{InsideTopBaffle^2 - F^2} \qquad Q = 8.036 \cdot in$$

$$W := \sqrt{InsideTopBaffle^2 + R^2} \qquad W = 8.591 \cdot in$$

$$G(D) := \frac{(D + F) \cdot \sin(InsideBladeAngle)}{\cos(InsideBladeAngle)}$$

$$Area(D) := Q \cdot \left(D + \frac{F}{2}\right) + G(D) \cdot \frac{D + F}{2}$$

$$Area(0 \cdot in) = 9.085 \cdot in^2$$

$$Area(1 \cdot in) = 17.833 \cdot in^2$$

Sanity-check the above formula, by calculating the area of a D=0 triangle via a slightly different formula.

$$\frac{InsideTopBaffle \cdot R}{2} = 9.085 \cdot in^2$$

Define formula for the inside-edge setback N inches down from the top.

$$IESB(N, D) := D + N \cdot \sin(InsideSetbackAngle)$$

Define the vertical dimension of the subenclosure, to be the total height of the drivers, plus several interspacings - one above, one between each pair of drivers, and one below.

$$SubenclosureHeight := 2 \cdot WooferDiameter + TweeterDiameter + 4 \cdot DriverSpacing$$

$$SubenclosureHeight = 23.118 \cdot in \qquad SEH := \frac{SubenclosureHeight}{in}$$

Define formula for the volume of the subenclosure, given the starting setback distance.

$$SEVol(D) := \int_0^{SEH} Area(IESB(y \cdot in, D)) \cdot in \, dy$$

Take an initial guess at the subwall setback distance, and use a solve block to find the setback which actually gives us the subenclosure volume that we want.

$$Dist := 6 \cdot in$$

Given

$$SEVol(Dist) = V_{midrange} \cdot (1 + FudgeFactor)$$

$$D := Find(Dist) \qquad D = 5.52 \cdot in \qquad D = 140.215 \cdot mm$$

Since the Scan-Speak 18W/8545 sticks back 80 mm from the baffle, this should work OK. Figure out the other interesting dimensions of this subwall.

$$SubenclosureWidth := Q + G(D) \qquad SubenclosureWidth = 10.118 \cdot in$$

$$SubenclosureHeight = 23.118 \cdot in$$

$$IESB(SubenclosureHeight, D) = 7.292 \cdot in$$

Let's see how things would work out if the subenclosure wall were pushed back to the 6-inch point, just for good measure.

$$FrontEdge := Q + G(6 \cdot in) \qquad BackEdge := FrontEdge + Wall \cdot \tan(InsideBladeAngle)$$

$$FrontEdge = 10.249 \cdot in \qquad BackEdge = 10.454 \cdot in$$

$$SEVol(6 \cdot in) = 1.002 \cdot ft^3$$

$$SEVol(D) = 0.935 \cdot ft^3$$

$$IESB(24 \cdot in, 6 \cdot in) = 7.839 \cdot in$$

That looks promising. It gives another 5% or so of subenclosure volume, which would allow for some additional volume being used up by interior bracing. I can always make the subenclosure smaller by inserting some foam blocks or something.

OK. The subenclosure wall is actually built using a 24-inch-tall piece of MDF. Figure out the dimensions of the midplate, which seals the bottom of the subenclosure and goes back forming a shelf brace across the rear of the cabinet.

$MidplateHeight := CabinetHeight - 24 \cdot in - Wall$ $\quad MidplateHeight = 15.25 \cdot in$

$InsideSetbackDistance := MidplateHeight \cdot \tan(InsideSetbackAngle)$

$OutsideSetbackDistance := MidplateHeight \cdot \tan(OutsideSetbackAngle)$

Show the inside setbacks

$InsideBladeAngle = 15.261 \cdot deg$

$InsideSetbackAngle = 4.396 \cdot deg$

$InsideSetbackDistance = 1.172 \cdot in$

$OutsideSetbackDistance = 1.131 \cdot in$

Calculate the midplate dimensions

$OutsideMid := OutsideBottom - OutsideSetbackDistance$ $\quad OutsideMid = 22.869 \cdot in$

$InsideMid := InsideBottom - InsideSetbackDistance$ $\quad InsideMid = 19.612 \cdot in$

Calculate the long diagonal on the midplate, and from this calculate the width of the baffle where it meets the midplate. The front of the midplate is narrower than the baffle, by two wall thicknesses minus a hair.

$MidDiagonal := \sqrt{InsideMid^2 + RearPlateWidth^2}$ $\quad MidDiagonal = 24.691 \cdot in$

$MidBaffleWidth := \sqrt{MidDiagonal^2 - OutsideMid^2}$ $\quad MidBaffleWidth = 9.308 \cdot in$

Figure out how far the outside end of the midplate hangs out past the inside, and how far from the inside wall this overhang is located.

$MidPointOverhang := MidBaffleWidth \cdot \sin(InsideBladeAngle)$ $\quad MidPointOverhang = 2.45 \cdot in$

$MidPointOffset := MidBaffleWidth \cdot \cos(InsideBladeAngle)$ $\quad MidPointOffset = 8.98 \cdot in$

$MidTotalLength := InsideMid + MidPointOverhang$ $\quad MidTotalLength = 22.063 \cdot in$

Now, let's figure out how things look if we account for the fact that we've got two wall-thicknesses to take off of the various edges. The front isn't cut back, the sides are narrowed by one thickness each, and the back is recessed by two thicknesses to account for the double-thick rear wall.

$ShaveSides := Wall \cdot (2 + \tan(InsideBladeAngle))$ $\quad ShaveSides = 1.705 \cdot in$

$MidFrontWidth := MidBaffleWidth - ShaveSides$ $\quad MidFrontWidth = 7.604 \cdot in$

$InsideMid_2 := InsideMid - 2 \cdot Wall$ $\quad InsideMid_2 = 18.112 \cdot in$

$OutsideMid_2 := OutsideMid - ShaveSides$ $\quad OutsideMid_2 = 21.165 \cdot in$

$MidRear := RearPlateWidth - ShaveSides$ $\quad MidRear = 13.295 \cdot in$

$$MidDiagonal := \sqrt{InsideMid_2^{\,2} + MidRear^2}$$ $$MidDiagonal = 22.468 \cdot in$$

Figure out how far the outside end of the midplate hangs out past the inside, and how far from the inside wall this overhang is located.

$$MidPointOverhang_2 := MidFrontWidth \cdot \sin(InsideBladeAngle)$$ $$MidPointOverhang_2 = 2.001 \cdot in$$

$$MidPointOffset_2 := MidFrontWidth \cdot \cos(InsideBladeAngle)$$ $$MidPointOffset_2 = 7.335 \cdot in$$

$$MidTotalLength_2 := InsideMid_2 + MidPointOverhang_2$$ $$MidTotalLength_2 = 20.114 \cdot in$$

Calculate the volume of the portion of the enclosure which lies to the rear of the subenclosure.

$$UpperRearVolume := \frac{MidRear + BackEdge}{2} \cdot SubenclosureHeight \cdot (InsideTop - 6 \cdot in - 3 \cdot Wall)$$

$$UpperRearVolume = 1.503 \cdot ft^3$$

$$LowerHeight := CabinetHeight - SubenclosureHeight - (3 \cdot Wall)$$

$$LowerHeight = 14.632 \cdot in$$

$$LowerVolume := \frac{BackEdge + (BaffleWidth - Wall \cdot 2)}{2} \cdot LowerHeight \cdot InsideBottom$$

$$LowerVolume = 1.58 \cdot ft^3$$

$$TotalVolume := UpperRearVolume + LowerVolume$$

$$TotalVolume = 3.083 \cdot ft^3$$

A bit on the low side, since it doesn't take into account the volume of the drivers and bracing, but the addition of stuffing should make it work out OK.